GSFC MO&DSD TECHNOLOGY DEVELOPMENT PLAN

TITLE: **COMMUNICATIONS & TELEMETRY TRANSPORT**	
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BRIEF TECHNICAL SUMMARY *(Objectives and Approach)*

This element addresses several communication technologies (such as antennas, coding, modulation, channel simulation) aimed at improving user access to the TDRSS. TDRSS is a valuable national asset used not only by NASA but by other elements of the government as well. It is important to NASA and the nation that this system be accessible to the widest possible range of users and applications.

APPROVALS		
WORK AREA MANAGER:	DIVISION MANAGER:	GSFC PROGRAM MANAGER:

JUSTIFICATION AND BENEFITS

The objective of this element is to develop ways in which existing Space Network users can obtain better performance in their communications systems and to expand the number of potential Space Network users by developing techniques whereby small-payload users will see the Space Network as a viable communications network for them.

All Low Earth Orbit (LEO) space missions supported by NASA and other federal agencies benefit by the adoption of standards that allow for cross-mission compatibility and commonality. This has payoff in reducing non-recurring costs for payloads and the capability to use cross-mission support for added flexibility. As the framework for preparing standards, support of current and proposed standards development with respect to data protocols and modulation formats for improved space communications is required. Support for the data transmission protocol development is needed in the form of the development of testbeds. These testbeds can provide simulation of the data transmission process as well as impairments to the transmission that may come from noise and interference processes in the transmission channel. Results of simulations with the testbeds can be used to improve the transmission protocols by identifying potential problems in the current protocol operation. These testbeds can also provide a future platform to assist users in verifying the correct operation of their payload. The testbed activity should also be of interest to the computer communications industry.

NASA has identified the small LEO satellite payload community as an important customer for the Space Network. Presently, that community is not convinced of the effectiveness of the Space Network to meet their communication and data transport needs. This can be overcome by showing the small-satellite community how access time with the SN can be competitive with a fixed ground station for data transport needs. The SN can also be competitive from a transmission power point of view if innovative antenna systems and coding techniques are applied.

Using antennas with modest gains will provide a significant improvement over many current designs and help overcome the power penalty for going through the SN rather than going directly to a proprietary ground station. Proper use of coding techniques will help to improve that data throughput when accessing the SN. Both of these techniques should allow for an overall savings in mission operations expense over developing proprietary ground stations.

Recent trends in spectrum allocation for space communications have resulted in the drive to use the available spectrum more efficiently. Future trends indicate that modulation and coding formats will need to be even more efficient of spectrum resources. Therefore, investigations in bandwidth-efficient modulation techniques, tied with coding techniques, are needed to respond to

NASA's current and future spectrum needs and allocation restrictions. The use of these techniques may lead to changes in receiver design, filtering, and power control for the communications system. These effects need to be understood as part of the overall design and system performance.

APPROACH AND PLAN

Task 1 - Small Satellite Access of the Space Network

The access modes for small satellites using a fixed antenna that is radially mounted on a spin-stabilized satellite have been shown by analysis to be feasible. This effort will be further developed by examining the potential for alternative placement of the antenna system on the satellite to see if the placement can be optimized and to see if similar possibilities exist for three-axis- stabilized satellites.

This task will include the following efforts:

a. Investigation of the effects of orbital elements upon the basic pointing solution for a spin-stabilized spacecraft using fixed antennas to access the SN. In this effort, we will be looking to determine if selection of ascending node location in conjunction with orbital inclination affects the contact statistics.

b. Investigation of the effects of the orbital elements on the optimal placement of antennas on a three-axis stabilized spacecraft to determine if a preferred orientation can maximize the contact statistics.

c. Continue the investigation of the potential of using Demand Assignment Multiple Access (DAMA) for accessing the SN. The current SN operations require advanced scheduling of communications support. Users will have greater potential for access if pooled resource blocks can be allocated for distribution in an "on-demand" manner. We have begun investigating how minimal changes to the current WSC configuration could accomplish this goal. Further development will concentrate on finishing the operational concept and the baseline design for how such a system might be realized within the WSC.

d. The concept of using a fixed, helical antenna for small satellite access of the SN is ready to move to its next stage of proof-of-concept testing. We propose the initial design work to configure a testbed to provide a simulation of the contact of a small satellite through the SN.

Task 2 - Coding and Performance Bounds

The study of the usage of a fixed antenna to access the SN from a small satellite showed that improved performance can be obtained by appropriate coding of the transmission to reduce the channel error rate due to the limited transmission power. The coding and performance studies need to be extended by considering the following efforts:

a. The preliminary studies did not include the effects of radio frequency interference (RFI) on the transmission. The sources of RFI can degrade the system performance, especially for low-power users. Interleaving of the signals is one potential method for overcoming RFI and other burst-interference noise sources. This technique will be analyzed to determine its effects on the proposed coding structure.

b. Extend the variable-rate coding concept developed during the initial investigation to variable channel rates.

c. Examine the realization details for variable rate coding and its usage with a Viterbi decoder.

d. Examine the performance of Automatic Repeat Queuing (ARQ) schemes instead of, or in conjunction with, variable rate coding.

e. Examine the requirements for realizable Trellis Codes.

f. Examine the use of Turbo codes in the Space Network channel.

g. Examine codes in relationship to the needs of bandwidth efficiency and transmission data frame size will be investigated. These include higher-rate codes, as examples: rate 3/4 and rate 7/8 codes. Also, the effects of non-white-noise channels on these codes and frames will be investigated.

Task 3 - Analysis of High-Order Modulation Techniques

The baseline modulation system for most systems is based on Quadrature Phase Shift Keying (QPSK) modulation. QPSK allows for the transmission of two data bits for every transmitted symbol. Higher order modulation techniques will allow for greater transmission efficiency (more bits per symbol) and therefore better utilization of the SN channel. Development of the baseline channel. Development of the baseline simulation model for 8-ary PSK modulation of a satellite through the SN will be the primary emphasis of this task. Once the simulation process has been completed, these results will be made available to the community through reports to the appropriate standards committee.

Task 4 - Space Protocol Testbed Development and Support

The Advanced Orbiting Systems (AOS) testbed has been developed to provide the means to simulate the transmission of data through a channel typical of that found in the SN. One element of that testbed effort has been the development at New Mexico State University (NMSU) of the Space to Ground Link Simulator for the testbed. This portion of the simulator will generate an output data stream that represents the hard decision output of the signal process elements found at the WSC. This will be useful for simulating the channel characteristics for SSA, KSA or MA services.

This includes the generation of error patterns, delay, and acquisition and tracking processes. Additionally, this task will require the interfacing of the NMSU components with those supplied by GSFC for the project.

Task 5 - Channel Coding

This task is intended to advance channel coding and modulation technoques for low Earth orbiting (LEO) satellite communication channels. The communications requirements for LEO satellites are to operate at a high data rate with constrained channel bandwidth and effective isotropic radiated power. Current coding techniques under investigations are Turbo codes, Reed Muller subcode RM(64,40), and Trellis coded modulation.

First NASA's future mission coding requirements are determined. Two investigators are chosen, who complement each other, one is an expert in convolutional codes and the other in block codes, so as to solve NASA's problem. These investigators coordinate these efforts between themselves, NASA and the coding community to ensure there are no duplication of effort.

The performances of the candidate codes are traded off and the optimal code is selected to be further studied.

The optimal code is designed and system studies are performed so as to mitigate risk before recommending as a solution. If the particular application has a broad community the code will be recommended as a standard.

.DELIVERABLES

ITEM	DATE
Communications and Telemetry Systems	
Task 1 - Small Satellite Access of the Space Network	
a.. Extend baseline concept for Demand Assignment Multiple Access (DAMA) system including simulations of expected performance	06/97
b. Perform analysis of additional antenna pointing cases	12/96
c. Complete baseline concept for antenna testbed	06/97
d. Report on baseline EUVE tests performed and an analysis of the results	12/96
Task 2 - Coding and Performance Bounds	
a. Complete architecture approval	12/96
b. Analysis of alternative code options	12/96
c. Complete analysis of a Doppler extractor for a DAMA service	01/97
Task 3 - Analysis of High-Order Modulation Techniques	
a. Complete extensions to basic studies	05/97
b. Report on coding and equalization extension studies	06/97
Task 4 - Space Protocol Testbed Development and Support	
a. Complete integration of system with Internet front end	05/97
b. Complete delay module construction and testing	05/97

ITEM	DATE
Task 5 - Channel Coding	
a. Report on Turbo code for bandwidth efficiency	09/97
b. Design and simulation of self-synchronizing Turbo code	09/97
c. Report on Trellis coded modulation techniques applied to Turbo coding	06/97

RESOURCE REQUIREMENTS

Task Name	**NASA UPN**	**FY97** *($K)*	**FY98** *($K)*	**FY99** *($K)*	**FY00** *($K)*	**FY01** *($K)*	**FY02** *($K)*
Communications and Telemetry Transport	(315-90-15)	300	300	300	300	300	300

GSFC MO&DSD TECHNOLOGY DEVELOPMENT PLAN

UPN: 315-90-15 COMMUNICATIONS & TELEMETRY TRANSPORT

SCHEDULE

COMMUNICATIONS & TELEMETRY TRANSPORT	FY97				FY98		FY99	FY00	FY01	FY02
	Q1	Q2	Q3	Q4	Q1/2	Q3/4				
Task 1 - Small Satellite Access of the SN:										
a. Extend baseline DAMA concept										
b. Analysis of antenna pointing cases										
c. Complete concept for antenna testbed										
d. Report on EUVE tests and analyses										
Task 2 - Coding & Performance Bounds:										
a. Complete architecture approval										
b. Analysis of alternative code options										
c. Complete analysis of Doppler Extractor										
Task 3 - Analysis of High-Order Modulation Techniques										
a. Complete extensions to basic studies										
b. Report on coding and equalization										
Task 4 - Space Protocol Testbed:										
a. Complete integration of system										
b. Complete delay module construction										
Task 5 - Channel Coding:										
a. Report on Turbo Code BW efficiency										
b. Design and sim. of self-sync.Turbo code										
c. Report on Trellis coded mod of Turbo coding										
Resources by FY($K):	300				300		300	300	300	300